Case Study – Cyclone Boiler SFC

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Abstract:

Under boiler installation of a submerged flight conveyor (SFC), as a retrofit to an existing unit, presents many engineering challenges. When performing a retrofit installation on a cyclone style unit, there are several unique challenges that need to be addressed. Some key differences between a typical pulverized coal unit and a cyclone unit are the shape and quantity of bottom ash discharge locations, the amount of bottom ash produced, the physical properties of the bottom ash (slag), and the types of ancillary systems affected.

In response to various federal regulations, utilities have been converting wet sluice style bottom ash handling systems at coal fired power plants to “dry” ash handling systems. A common retrofit of these boilers involves the demolition of the existing wet ash hoppers, along with all associated sluicing equipment for replacement with a submerged chain conveyor. Submerged chain or submerged flight conveyors (SFCs) have been installed as original equipment on many newer coal units and have been retrofitted to many existing units.

The majority of these installations are on pulverized coal (PC) style boilers. Accordingly, the design evolution of the SFC has generally followed the path of optimization for PC boilers. Some design aspects of SFCs make for some interesting design and installation challenges for both the SFC themselves and the balance of plant work required for installation.

PC boilers work by burning coal which has been crushed to a size so fine that it can be burned as a suspension within the furnace. The combustion rate of coal is related to the total surface area of the particle, a smaller particle size has proportionately more surface area and burns more quickly. Pulverizing coal to a very fine particle size results in the particle completely combusting in a matter of seconds.

Cyclone furnaces were developed by Babcock and Wilcox to burn grades of coal which produce ash with low melting temperatures. The low residence time in PC boilers results in molten ash solidifying on various parts of the boiler backpass. Cyclone boilers burn larger particles in large burners located outside of the boiler box, called cyclones. Due to the longer residence time in the boiler, the molten ash falls out of the bottom of the boiler in the form of slag, rather than solid bottom ash.

The increased residence time also changes the amounts of bottom ash/slag. A typical PC boiler might discharge 80% of the ash in the outlet gas stream (fly ash), with the
remainder falling out as bottom ash. For a Cyclone unit, those proportions are flipped, with the majority of the ash leaving the boiler as molten slag.

Cyclone slag has several other unique characteristics compared to PC bottom ash. PC bottom ash has little opportunity for beneficial re-use. Slag can be sold for use as roofing material or blasting grit. A major design consideration for PC boilers is the reinforcement of the SFC to withstand the severe impact loads resulting from car sized clinker falls. There is no such concern with respect to the liquid slag discharge from a cyclone boiler.

The geometry of a PC boiler allows only two options for orientation of the SFC: in-line with the length of the boiler in either direction. It must be installed parallel to the boiler center-line. Some degree of offset is possible, but generally speaking, SFCs are installed with their centerlines coincident with the boiler centerline.

The discrete circular slag taps of a cyclone style boiler allow for a wide array of options for arrangement and orientations of SFCs. Just like would be installed on a PC boiler, an SFC can be oriented coincident with the centerline of the boiler. This SFC collects slag from both slag taps and carries the solidified ash out of the boiler building in that same direction.

The second option is to install a dedicated SFC per slag tap. The circular shape of the slag tap allows for each SFC to be installed rotated until it interferes with the other one. This flexibility means that many different arrangements for SFC discharges can be used. CDG performed a conceptual design study for a two-unit cyclone plant near St. Louis where, in order to fit under boiler SFCs on both units and have them be able to discharge outside of the building, an arrangement featuring a ~5 degree offset on one boiler's mostly in-line SFC was developed, which then discharged into another SFC parallel to the second unit. The SFCs associated with each unit penetrated the unit wall next to each other and discharged into a common ash hopper.

The third commonly studied installation, which has been installed in at least one plant, is the three SFC arrangement. Each slag tap gets a dedicated SFC, oriented orthogonally to the boiler centerline. These SFCs both discharge into a third SFC, which performs the dewatering and transports the ash out of the boiler building. If the individual SFCs on the slag taps are long enough to perform adequate dewatering, the SFCs can discharge to a common belt conveyor for transportation out of the boiler building.

At New Madrid, the decision was made to install the SFCs coincident with the boiler centerlines. The SFCs of the two units both discharge to a common structure in between the units. The structure has chutework which can take the dewatered slag to either a belt conveyor or discharge directly into a concrete bunker below. The belt conveyor is the primary means of ash discharge, so that truck loading can be performed outside of the main work areas of the plant. The concrete bunker in between the units is only used for emergency discharge in the event that the belt conveyor goes down.
An SFC is connected to the boiler above via seal troughs along the perimeter of the boiler. The discharges of a cyclone boiler, known as slag necks, are connected to the SFC either by extension directly into the water trough, or by a circular seal weirs added to seal boxes connected to the top of the SFC. New Madrid uses the seal box arrangement. The seal box arrangement allows for some air space between the water and the slag necks, which allows for easier venting of the slag necks without the induction of slag or water.

As stated previously, PC boilers regularly produce large clinkers which must be broken before they can be carried up the dewatering ramp. The first stage of breaking up the clinkers is performed by the water bath itself, by means of thermal shock. For clinkers that need to be reduced in size further, an access platform is typically provided above the bend of the SFC where the ramp exits the water bath. From that platform, plant personnel can manually break clinkers. Similarly, cyclone boilers discharge molten slag, through narrow diameter slag necks. Oversize clinkers cannot physically make it out of the boiler without melting, which means that bend area platform access is not necessary for cyclone boiler SFCs. However, the slag necks themselves have associated piping and access holes which require personnel access.

For both PC and Cyclone units, ash from the economizers can be disposed of along with the bottom ash/slag. A typical arrangement includes smaller dry drag chain conveyors, or dry flight conveyors (DFCs). One DFC is used to collect the output of the economizer hoppers, and generally a second one is used to transport the economizer ash to the SFC below. Although the PC/cyclones arrangements are very similar technically, they are potentially quite different economically. Because Cyclone slag can be sold, rather than just landfilled, mixing the non-saleable economizer ash results in reducing the value of the product. Analysis should be performed which compares the operational benefit of combining economizer and SFC ash to the reduction in value of the SFC discharge material.

Not every Cyclone unit is suitable for under boiler SFC retrofit, it is important to be aware of the engineering challenges that can arise during a retrofit under boiler installation of an SFC and effectively address them early in the design.